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13. ABSTRACT *(Maximum 200 Words)* The 1800s wooden sailing ship could travel to any point in the world and establish maritime supremacy but the cost of operation included the sickening and killing the over-crowded crew. Iron shipbuilding allowed safer, larger ships. Compartments in iron ships created internal communications problem gradually solved with mechanical devices. The need to protect large ships from torpedoes meant that small ships were power-driven into seas up to the limits of human endurance. The ships developed their own "nervous system" allowing a central fire control director to remotely fire every gun in the ship. Slowly sailing ship living standards were replaced with bunks, sanitary spaces and messrooms. The elimination of portholes increased the structural soundness of warships but cut the sailors off from fresh air, and a glimpse of the outside. The USN adoption of the peacetime-forward-deployment meant sending ships to sea for 100-200 day periods. The loss of overseas bases and the threat of terrorist attack, such as on the USS *Cole*, has greatly complicated going ashore for liberty compared to the 1950-60s. Sailors have lost places topside to quietly view the sea and sky. The seaman is gradually losing the pleasure of the contact with the ocean.

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Philip Sims

Ships and the Sailors inside Them

ABSTRACT

Wooden warships sickened and killed their own crews due to poor food, disease and dangerous work. Iron shipbuilding allowed safer and healthier ships but their internal compartmentation created communication problems which were gradually solved with mechanical systems. Ships developed their own "nervous system" allowing a central director to fire every gun.

The creation of high-powered machinery meant that small ships were driven into seas up to the limits of human endurance. Coal fuel created its own back-breaking workload and industrial hazards until replaced by oil.

The displacement limits in arms reduction treaties forced Navies to study trading-off crew quality with carrying more armament.

The adoption of the peacetime-forward-deployment mission meant sending ships to sea for 100-200 day periods that hadn't been seen since the days of sail. The loss of overseas bases and the threat of terrorist attack has greatly complicated going ashore for liberty compared to the 1950-60s.

The long term trend of sailor's job has been changing from providing muscle to brains. On submarines, aircraft carriers and low-signature surface combatants, sailors have lost places topside to quietly view the sea and sky. The seaman is gradually losing the pleasure of the contact with the ocean.

INTRODUCTION

This paper will describe the changing relationship between warships and the sailors inside them over the last 300 years. Things that are commonly thought as ancient practice, such as using hammocks for the crew sleeping, lasted well into the 20th century. Things that are thought of as modern, such as worrying about human factors, began to emerge in the nineteenth century.

THE WOODEN SAILING SHIP

Perfected over 400 years, the European wooden sailing ship could accurately travel to any point in the world, with no logistics support, and establish maritime technological supremacy over the local navies (Figure 1).

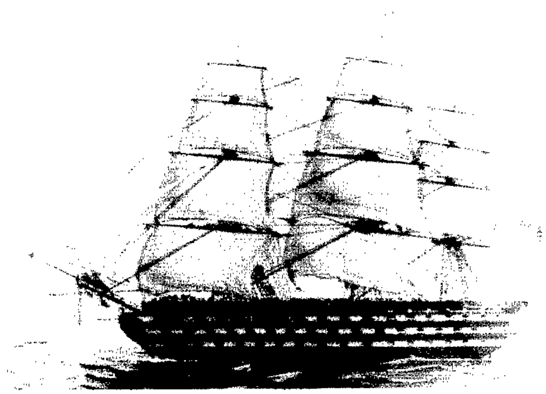

Figure 1: USS *Pennsylvania*, wooden ship of the line. Although the wind from aft fills the sails, the artist shows the flag streaming astern. (NHC)

The price of their success was inflicted on the men inside. During the 13 years of struggle with revolutionary France (1792-1815), fought all over the world, the casualties of the Royal Navy were (Lloyd, 1968):

Cause	Deaths	Percent
Enemy Acton	6, 540	6.3
Foundering, Wreck, Fire	12,440	12.2
Disease and Accident	84,440	81.5

Many more sailors were sent to hospitals; as many as 1 in 3 sailors in 1782 and, even after the Napoleonic wars, 1 out of 8 sailors became sick enough to be hospitalized every year. (Allison, 1943)

The diseases that swept through the ships included tuberculoses, yellow fever, small pox, dysentery, malaria and scurvy. The primary cause was simple over-crowding. The HMS *Victory*, 186 feet long by 51 ft of beam, carried a crew of 821 men at Trafalgar.

Key to the success of the European sailing ship, allowing it to be large and travel great distances without being repaired, was the invention of a successful bilge pump. However, the sailing ship's bilge pump lifted water to the gun deck and dumped it there, to run over the side by scuppers – leaving the crew walking up and down the ship to pass across whatever was being pumped up.

The diet of salted meat and hardtack was both empty calories and monotonous. The Channel Fleet in 1780, after a six week's cruise, landed 2,400 sailors incapacitated by scurvy (Lloyd, 1968). The water, stored in wooden barrels, often "turned to slime" as the voyage went on.

Since a square rigger could not point into the wind very well, the wind was normally from astern. The air first went to the officers' accommodations in the stern, then, in order, the marines, the midshipmen, the sailors, the food animals and, finally, the "head".

The crew slept in hammocks over the guns (Figure 2) and ate in the same area from tables lowered on ropes from the overhead

Figure 2: Hammocks on the gun deck (NHC)

Working the masts (Figure 3) in brutal weather produced fatal falls to the deck and, due to being bent over the yard pulling on the canvas, one-in-seven sailors had a hernia. (Pope, 1981) It was considered a great step forward when the Royal Navy started providing free hernia trusses. Unhealed flogging wounds could become inflected. Upon arriving in a port, binge alcoholism and venereal disease also took their toll since "the majority of the able and ordinary seamen and many petty officers got drunk on every opportunity." (Seaman's Life, 1880s) The introduction of rum mixed with water ("grog"), which would spoil if kept too long, was intended to prevent crewmen from saving up their pure rum issue for a roaring drunk onboard. (Pack, 1983)

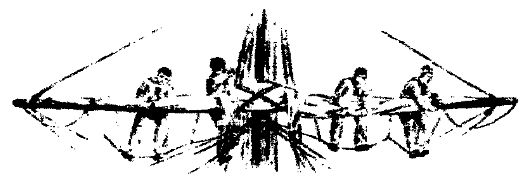

Figure 3: With their feet on man-ropes sailors would bend over the yard pulling up hundreds of pound of wet canvas. (NHC)

The number of men in the Royal Navy, shown in Figure 4, fluctuated widely between around 15,000 men in peace, in order to save money, and 100,000-150,00 men during a war. (Lloyd, 1968) This surging meant the Royal Navy was either impressing everyone the press gang ran across or, alternatively, dumping thousands of unemployed sailors into port towns

The ability to surge up and down was a result of the static technology of ship design of the time. A ship could be "hulked", stripped of guns and rigging, and left afloat under a caretaker crew. At next crisis, a quickly rearmed ship would be a first-line unit. An even more economical approach was to build the hull but not launch it. Stored in a building shed, the ship would not even suffer from the wear and tear of the weather but could be quickly launched and outfitted.

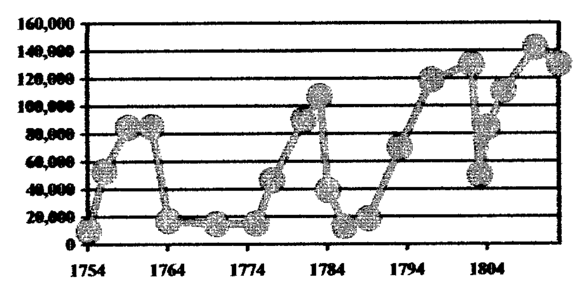

Figure 4: Men in service in the Royal Navy 1854-1810

The Royal Navy had defeated the Spanish and French navies at Trafalgar in 1805 and was gradually reducing in size, after an 1811 peak in manning, when it continued to harass American merchant ships and warships seeking to impress sailors. What they needed were sailors to replace the ones that were dying or being invalided out of their existing fleet. The Royal Navy had mortality rate, between 1811-1813, of 33 men per 1000 sailors in a Navy averaging 138,000 men. (Lloyd, 1963) The War of 1812 was caused by the lethal nature of wooden sailing ships.

The internal communications of a wooden sailing ship was by "midshipman internet". The captain would give the midshipman a message. He would make a circuit of the ship, find the recipient and get a reply. Then the messenger would locate the captain, even if he had physically moved, and give him the response.

The crews were not paid a salary while serving on a ship. When the ship was taken out of service for a yard period, they were given a lump sum (hence the term, "paid off"). There were people outside the gates of every naval base dedicated to detaching that money from the newly rich sailor. A 1757 reform allowed allotment of a portion of the future pay to relatives ashore.

STEEL AND STEAM 1855-1945

The start of reform

While the fact that lemons could stop scurvy was published in 1753, lemons or limes were not issued to the crews of Royal Navy ships until 1795. The invention of the tin can in 1810 allowed a better variety of food to be preserved, although the new technology had a few problems at first. The lead solder on cans has been suggested as the source of poisoning the crew of the Franklin Arctic expedition of 1853.

In 1859 the idea of enlistment for ratings was introduced; they were signed on for ten years at the age of eighteen. (Russel , 1999) They were paid a monthly salary whether they were on a voyage or not. In between ships, the sailors had to be put somewhere. The traditional answer was using the hulks of old sailing ships; the idea being that old ships would be good for training and they were already paid for. The accommodations were spartan, unhealthy for the same reasons as other wooden ships and, for those anchored out, required considerable effort in rowing people to-and-from them. In the interest of providing better conditions for ratings, Plymouth opened its first land barracks June 5, 1889 which was equipped with laundry and bakery. The old officers were not impressed. After a June 1892 inspection, the First Sea Lord Admiral Sir Anthony Hoskins stated that he "had never seen such a wicked waste of money as the barracks had cost." (Russel, 1999)

End of Sail

The period from approximately 1865 to 1885 was a struggle between the fading away of a generation of old men raised on sailing ships and their replacement with rising young men who believed in steam and science. The old men had a few specific rationales for retaining sail (saving fuel, emergency take home power, damping rolling) and a vague emotional one that rigging sails in storm made the British sailor into the hardy and courageous seaman that could defeat those of any other nation. As late as 1914, a lament for sail claimed the "The abolition of masts and yards on board a man-of-war had one most serious effect, which was that it did away at a stroke with one of the finest forms of physical training." (London Times, 1914)

Representing the innovators, Captain Fitzgerald wrote, "The men read now much more than they used to, and they know perfectly well that a high state of efficiency in 'shifting topsails' will be no use to them in wartime, nor enable them to fight their ship any better than if they has never seen a topsail in their lives. They look upon it as a gymnasium at which so much useless work is done, like carrying shot or any other manual labour" (Parkes, 1972 pg 261) As to saving fuel, it was calculated that the weight and air drag of the sails on a ship under power ate up any savings of fuel during the small amount time put in under sail. As ships

were built with thick armor belts, large machinery and big guns, the tons-of-ship-to-be-moved per square-feet-of-sail continued to increase until sails could barely move them anyway (Figure 5).

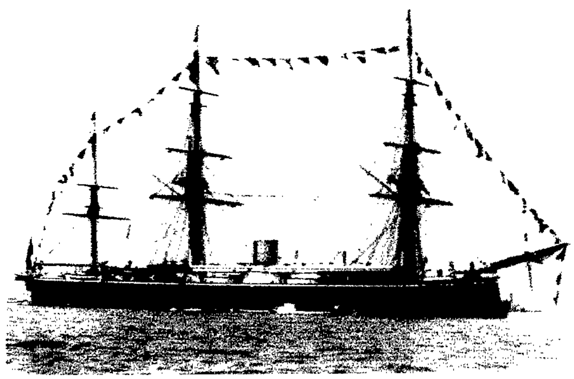

Figure 5 The HMS *Monarch*, a turreted battleship from the transition of steam plus sail to a true steam ship. (NHS)

With the sails gone, many of the larger ships of the Royal Navy were fitted with deployable anti-torpedo nets which can be seen as pipes stored alongside the hull in photographs. The use at sea of the nets so increased the drag that it harmed the ships speed and maneuverability but in-port they could protect a ship at anchor from a surprise attack. There is some suspicion that the anti-torpedo nets remained fitted to Royal Navy ship well into World War I primarily because rigging them out from the side of the ship required sailorly skills similar to working the rigging. (Parkes, 1972 pg 327) The nets were removed in the middle of WWI due to the risk that, if damaged by shot in battle, the stored nets could trail back and foul the propellers.

Treatment of Sailors Onboard

The crews continued to sleep in hammocks, bathed-in-buckets, and eating where one slept from lowered tables. The crew would holystone the wood on the deck clean (Figure 6) and then it could also be used as the laundry for their uniforms (Figure 7).

One could flog an impressed landsman into performing correctly the semi-robotic actions of loading a smooth bore cannon on a sailing ship but one can not flog a machinest mate into doing better lathe work. The introduction of technology in ships (and social reforms ashore) led to a long term decline in the number of floggings from 60 per 1000 sailors in 1830 to 5 per 1000 in 1865. (Rasor, 1976) After the mid-1860s, flogging in peacetime, although still legal, was essentially stopped altogether.

It is difficult to significantly sabotage a sailing ship without risking the lives of yourself and fellow crewmen However, a steam ship, filled with delicate machinery, provides many options for protest, especially when the crew was still berthed in spaces with the guns. The preferred way to express crew dissatisfaction with their officers in the Royal Navy between 1900 and WWI was to unbolt the optical gun sights and throw them overboard. (Carew, 1981) The ship remained mechanically safe and sound but was useless as a warship. Ships have always had secure off-limits spaces (for cash, rum, and the magazines) but the potential for this kind of protest has, over the long term, promoted designs with more locked compartmentation around delicate machinery, weapons and electronics.

Figure 6: Holystoning the wooden deck clean. (NHC)

Figure 7: The weather deck was also the laundry. (NHC)

The US Battleship *Missouri* of 1903 included the first installation in a US warship of modern kitchen conveniences such as a dish washing machine, potato peeler and masher, ice cream and dough mixing machines, meat slicers and steam tables to keep food warm. (Firebaugh, 2000)

Coal and Steam

The first steam ships tried to use sea water in their boilers but salt scale formation made fitting the ships with distillers worthwhile. Since the ship boilers now had a source of clean water, some of it was given to the crew. The dependable steam-propelled motion into the wind allowed fitting cowls to bring fresh air down to any compartment in the ship.

One of the most hated tasks on a ship was the all-hands drill of coaling ship. Since the larger ships had side armor belts precluding loading from barges alongside by chutes, the coal was dumped on deck and shoveled into deck holes leading down, through temporary canvas pipes, to the bunkers below (Figure 8). The bunkers then had to be trimmed to spread out the load. Coal dust was everywhere and including all over the crew's outside and lungs. After coaling came cleaning the entire ship to get rid of the dust.

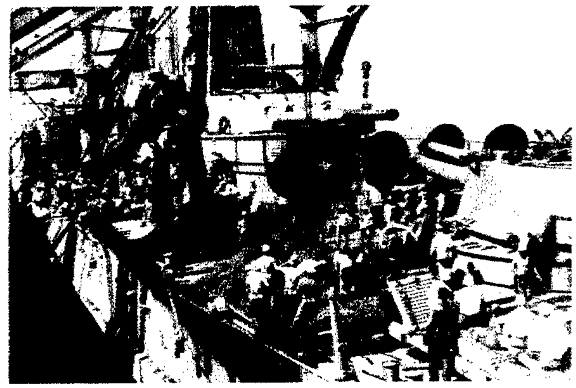

Figure 8: Coaling ship with bulk coal dumped on deck to be stowed below. (NHC)

Machinery also brought into the ship poisonous heavy metals such as mercury (for thermometers and inclinometers), cadmium (for plating rubbing surfaces), lead (for babbitted bearings and batteries) and tin (for solder). The cheap, effective and easy-to-form asbestos insulation was placed all over the engine room.

The *Monitor*, so far ahead of her time in military features, was also the first ship to have to support its crew with completely artificial lighting and artificial ventilation. Since the living spaces were below the waterline, it also required Ericsson to invent the first below-water toilet with its own hand pump and valves.

The cruiser *New York* of 1893, substituting machinery for human muscle, has 92 separate steam engines totaling 170 steam cylinders. (Firebaugh, 2000) They were used directly for work like raising anchors or indirectly to produce hydraulic power to turn the turrets. This dispersed use of steam meant pipes running through various compartments putting unintended radiant heat into them, even in the tropics, raising the temperature as much as 8 degrees. (Firebaugh, 2000) The engines themselves leaked steam, putting heat and humidity into any compartment where they were located. Trials on the *Brooklyn* in 1896 of electric turret training demonstrated the functional superiority of that system. Electric cables did not heat compartment that they passed through and electric motors, while discharging heat, at least did not add water to the air. In combat, shell splinters cutting a cable would not dump scalding steam into a compartment as a fractured pipe would. The introduction of

electric lighting was gradual with the 1890s vintage torpedo-boat-destroyers having it installed only in the machinery spaces, and depending on candles and oil lamps elsewhere. The first British destroyer class to have all electric lighting was the *Rivers* of 1903.

The Dark Ages of the USN

While the European Navies were being reformed and installing new technology, the USN regressed back to wooden hulled ships which, although fitted with steam, carried a heavy sail rig. There as certain logic to this since the ships were sent to remote parts of the world as show-the-flag station ships. The ability to copper a wooden hull and use of sail, which increased its independence from shore coaling, were of value in such a mission. However, a retreat in technology also meant no improvements in the treatment of sailors. Captain Shufeldt, Chief of the Bureau of Equipment and Recruiting, reported in 1876 that "It is a rare thing to see anything in the outfit of a man of war intended to enhance the comfort or even protect the health of the enlisted man". (Harrod 1978) The navy's Medical Inspector complained of the lack of fresh air below and even that stale air was being contaminated by the ammonia and other gases coming off the stored coal. (Gibon 1877)

As the New Navy emerged, a theme would be sounded that would be a problem through out the 20th century: the struggle between need for quality sailors against the cost of giving them decent living standards. In 1891, an essay argued that "A modern ship, being a complicated machine, requires the most intelligent kind of men to handle and fight her effectively" and "In the smaller cruisers, flesh and blood will not stand any further sacrifice to illusive offensive power on a small displacement" (Niblack, 1891) The same author makes a list of needed changes that would continually reoccur:

- move the crew berthing away from heat, noise and bad smells.
- adequately ventilate and light all the spaces.
- provide the crew members with more personal gear stowage.

Internal Communications

Iron shipbuilding allowed safer, larger ships with bulkheading breaking the internal spaces into compartments. The existence of compartments, and the greater need to pass precise instructions about machinery, created a communication problem gradually solved with voice tubes, engine room telegraphs (Figure 9) and pointer systems.

Voice tubes were tried but had a series of problems; the first of which to get the attention of the recipient – the shrill whistle preceding a modern announcement at sea is a legacy to the whistle used to call a recipient to a voice tube. Voice tubes required the two individuals to alternate speaking into and putting their ear to the tube. Weather deck voice tubes were affected by blowing wind. (Firebaugh, 2000 p 50). Voice tubes low in the ship were potential flooding routes if left uncapped. If routed over long distances, with many turns, the effectiveness of sound transmission was poor. Voice tubes, however, were still being fitted in ships during World War Two. Sometime they transmitted more than what was expected. After a shell from the *Bismarck* hit the *Prince of Wales* bridge, the chartroom personnel, deep in hull the noticed something coming out of the tube. It was blood from a bridge officer collapsed over the upper end of the tube.

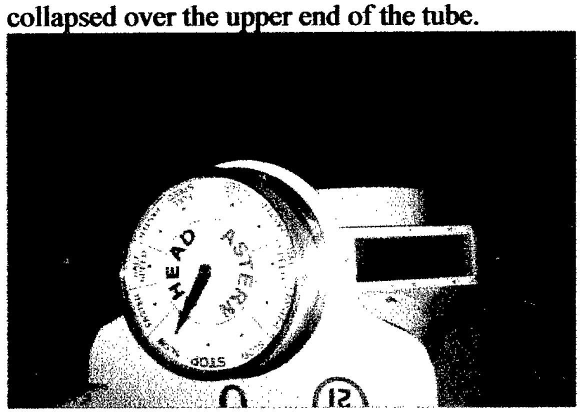

Figure 9: The 'telegraph' was a way to accurately pass information to engineers below in a noisy engine room.

However, in the Sino-Japanese and Russo-Japanese wars, the ship were still dependent on runners to carry messages to stations throughout

a ship. After the Battle of the Yalu, a Chinese ship's captain is reported that his experience showed "..that, in a modern action, a commanding officer, after a few moments, is half blind and totally deaf." (Firebaugh 2000)

The traditional role of the gunner-pointing-his-own-gun lasted up through the Spanish American War with inevitable inaccuracy at long ranges. To effectively utilize the long range of modern guns, the ships developed their own "nervous system" allowing a central fire control director to remotely point and fire every gun in the ship (Figure 10). Optical directors on tall tripod masts fed information on enemy movements to a central plotting station that instructed the turrets to aim. The guns were kept level, in spite of ship's motions, by instructions from gyroscopes deep in the hull. The actual firing was remotely done in the plotting station.

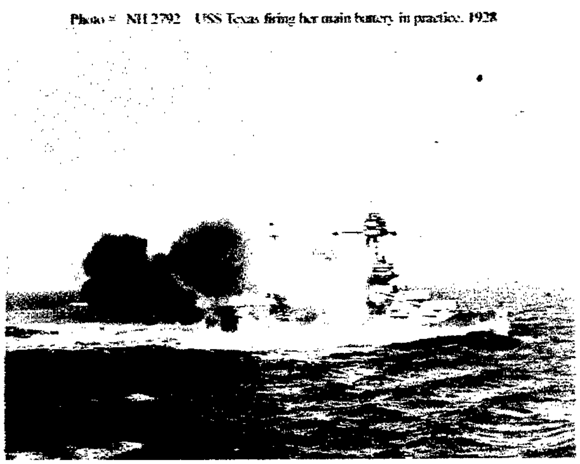

Figure 10: Guns on the *Texas* aimed and fired by a central fire control system. (NHC)

Small Ships in Large Seas

In the days of sail, small ships did not escort larger ships and were naturally expected to shorten sail in a storm and fall behind. The torpedo changed everything; the small ships were expected to remain on a fixed perimeter protecting the fleet in all weather conditions. Lightweight high-powered machinery fitted to narrow (for high speed) hulls meant that, for the first time, small ships were power-driven into seas up to the limits of human endurance (Figures 11, 12, 13). An American constructor described the problems '.... with even the largest of our torpedo boats, which have been found to wear out the crew in a very few days, principally by excessive and lively rolling." (Friedman 1982)

The British 1893 *Daring* class torpedo boat destroyers were 260 tons displacement, 185 feet long and capable of 27 knots. A captain of one reported "(Ship's) behavior and accommodation such that no one gets undisturbed rest at sea even in fine weather, in bad, very little rest for anyone.... In all compartments sweating is excessive, especially in Engine Room Artificer and stoker's messes.... Constant dripping. Stokers have to wash on deck, seems desirable they should have hot water... I recommend a small boiler." (March 1966) The crews were paid "hard-lying" money for the discomfort of serving in the torpedo boats. (March 1966).

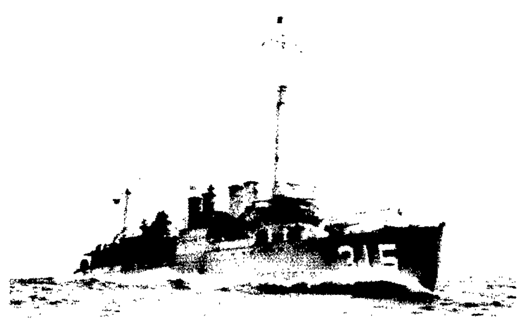

Figure 11: 1,200 ton destroyers were capable of 35 knots in calm water in the early 1900s. (NHC)

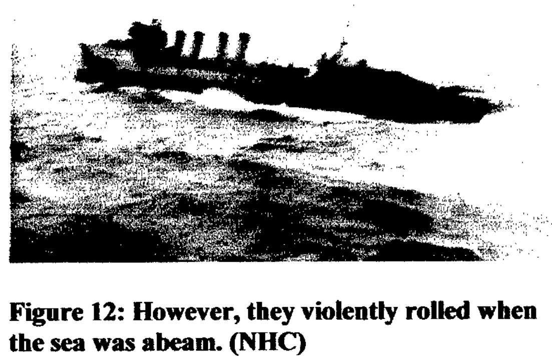

Figure 12: However, they violently rolled when the sea was abeam. (NHC)

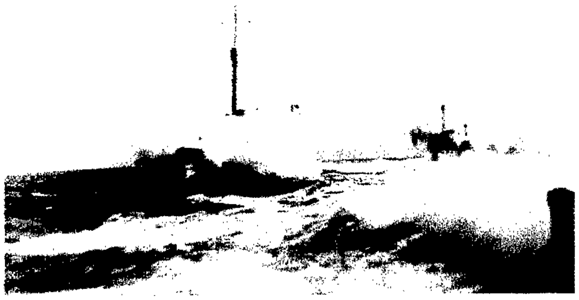

Figure 12: They crashed through when the seas were from ahead. (NHC)

In an early venture into Comparative Naval Architecture, the Royal Navy compared their destroyers with German ones which were visited in the early 1900s. They found the German ships with cabins for all officers (British engineers had none and, thus, no place to do paperwork), electric fans for hot weather and steam heating for cold. In very hot climates, water could be run over the weather deck to keep down the solar loads. The German ships had more effective bridge weather screen. In a early glimmer of human factors, the report states "…..to obtain maximum efficiency of the vessel it is of first importance that the officers shall be at their maximum efficiency, i.e. rested, keen , alert and not half stupefied by exposure to weather, or with their wits dulled by lack of sleep or excessive heat or cold.' (March 1966) It is measure of the Edwardian class structure that the writer was concerned only with the officers.

Trying to get an adequate number of convoy escorts in WWII, the Royal Navy used *Flower* class corvettes, originally intended for coastal patrols and minesweeping, as mid-Atlantic escorts. The short (205 ft overall) and lightweight (1250 tons full load) ships took a severe beating in that role. One history noted, "The strain on the ships' companies in the latter service (mid-ocean) was very great (and when oiling-at-sea facilities became standard) was the limiting endurance factor…." (Elliott 1977) Another history states "these new small escort ships were found to be almost useless in winter' partially because of their excessive rolling in a seaway – which exhausted their crews……." (Kemp 1978) David K. Brown writes of them, "The early, short forecastle '*Flowers*' were the worst. They had bunks in the forecastle where the motion was worst and to reach the bridge or engine room meant crossing the open well deck, inevitably getting soaked in rough weather. Worse still, the galley was aft and food had to be brought along the open deck to the mess, getting cold if not spilt on the way. As more equipment was added, overcrowding got worse." (Brown, 2000) He also mentions poor ventilation contributed to a high incidence of tuberculosis among *Flower* class crews.

Unintended Results of a Fleet Structure Change

Not only do individual ships have a social structure but entire fleets have a built-in social structure and introduction of large numbers of new ships to that fleet can have unanticipated results. During Word War I, the German Navy conducted a massive expansion of its submarine arm with the intent to starve Britain before the Americans, brought into the war by the resumption of submarine warfare, could arrive in any numbers. Chafing at being blockaded in port, the most ambitious and talented young officers and enlisted men transferred to the U-boat arm where they could see action. (Bassett, 1921) This left the battlefleet commanded by the older pre-war officers, with their policy of strict discipline, and manned by crews bereft of the natural pro-navy leaders among themselves. (Stumpf, 1967) The undecided middle came under the influence of the disaffected few which led to the fleet's mutiny which, in turn, inspired mass civilian unrest that brought down the Kaiser's government.

Coming of Oil

The first oil fired British battleship, the *Queen Elizabeth,* had a bronzed shovel mounted on the bulkhead near their refueling pipes, lest the crew forget what they were avoiding.

The adaptation of oil ended the need for the dirty manual labor of coaling the boiler at sea. A destroyer leader could consume 4-1/2 tons of coal per hour at full power with all of it being manually shoveled in at the rate of 30 pounds per shovel full. (March, 1966). Since with oil fuel, the furnace doors did not have to be kept open for shoveling coal, considerably less heat went into the engine room. A second crew reduction benefit was the reduced number of boiler tenders since the ash and slag no longer had to be removed every three to four hours. (March 1966) A ship could be refueled by a small detachment in one-third of the time it took the entire crew to coal a ship.

There had been sporadic attempts by the US Navy to re-coal at sea because the US Navy lacked the world wide coaling bases of the European colonial powers. The US built several large coaliers but coaling at sea was even more cumbersome than at a pier and still an exhausting all-hands drill. The coming of oil made moving fuel replenishment possible with minimal workload on the crew (Figure 14)

Oil had the disadvantages of requiring tight tankage bulkhead construction and gave off more volatile and smelly gases than coal. The venting had to be carefully designed to prevent an accumulation of vapors anywhere in the ship.

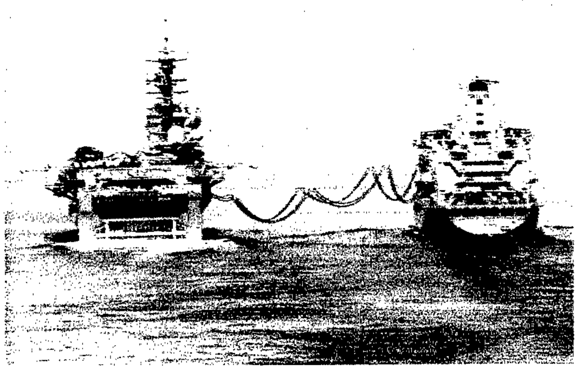

Figure 14: Rapid fuel transfer at sea while both ships are moving was made possible by oil. (USN)

USN and RN Ships Compared

Once it entered the war, the United stated sent its most modern coal-fired battleships to reinforce the Grand Fleet at Scapa Flow as the Fifth Battle Squadron. The newer oil fired ships were retained in the United States because of the scarcity of oil in wartime England. The two fleets, having a chance to exchange visit, got a good look at each other's ships. The British admired the American luxuries (barber shops, dentists, reading rooms, oil-fired galley, electric bakery and generous officer staterooms) but found the heads crowded with little privacy. (Brown 2000)

Disarmament Treaties

Naval arms reduction treaties made the Navies have to face the trade-off of habitability quality with carrying armament or machinery since the 'standard displacement' (full load but without fuel or reserve feed water) of each ship type was fixed by the treaties. In one study done for the Battleship Advisory Board, reducing habitability standards to primitive 1897 standards would save 435 tons and that weight could be spent on additional machinery to raise the speed from 27 knots to 30. (Muir 1976) The rival Japanese ships did not have laundries or ice cream machines and still berthed their sailors in hammocks. The Americans designers were also aware that the deck heights that fit the taller American sailor cost 420 tons on a 35,000 ton battleship compared to a ship with Japanese deck heights. Because the cruiser designers were trying to fit under a 10,000 ton treaty limit, there was considerable controversy about fitting the *Northampton* class cruisers with bunks for the entire crew; this would result in the *Northampton*, Figure 15, being first large US ship to be so fitted. (Friedman 1984) Pipe rack bunks increased the area per man 15 percent and changed a multi-use space (sleeping, assembly, recreation, messing) into single purpose sleeping areas (Figure 16). There was also the concern that solid parts of bunks would be thrown about by enemy damage, risking injury to the crew and blocking damage control efforts in way that stowed hammocks would not.

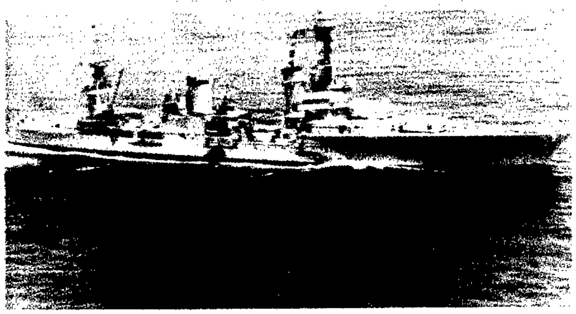

Figure 15: The Northampton, CA 26, pipe rack bunk test ship

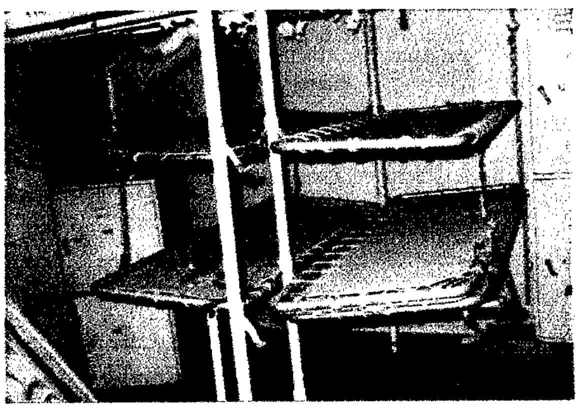

Figure 16: The replacement for the hammock was the canvas rigged pipe rack bunk

In the end, however, the decision was to go with quality support features for the all volunteer crews of the time since, as one admiral remarked, "Men would not live on a battleship today under the same condition they did forty-one years ago." (Muir 1976) Even with a depression ongoing, the Navy still had to make life at sea at least tolerable to standards influenced by the outside civilian world. The agonizing over crew versus armament by the US was ironic because the Japanese had resolved the problems of ship size limitations by deliberately cheating on the treaty constraints.

Human Factors and Systems Engineering

While "Human Factors" and "System Engineering" as defined design approaches are a post-WWII invention, the engineers working on re-activating the *Iowa* class battleships during the 1980s could see that the design included many features that resulted from deep knowledge of what the crew would naturally want to do. The ships had on the second deck single watertight door port-and-starboard passageways except for two bulkheads with side-by-side single watertight doors on the port side aft. The reason for this was a mystery until the first lunch on the first sea trial; the chow line snaked back along the passageway going through, and blocking, one door. The other door remained clear for fore-and-aft traffic.

The fore tower had an intertwined up and down ladder systems to separate personnel flows during rush to battle stations. The battleships were also fitted with monorails and aligned hatches to ease maintenance of large but removable items, such as pumps, by assisting in taking them directly to the shops. Hatches leading to deep storerooms were vertically aligned, with cranes and rope fittings, allowing a direct drop of new supplies below.

Compartmentation

Ships built in the mid-1930s had portholes and portlights (Figure 17) but as war approached they replaced with hull plating (Figure 18). The elimination of portholes increased the structural soundness of warships but cut the sailors off.

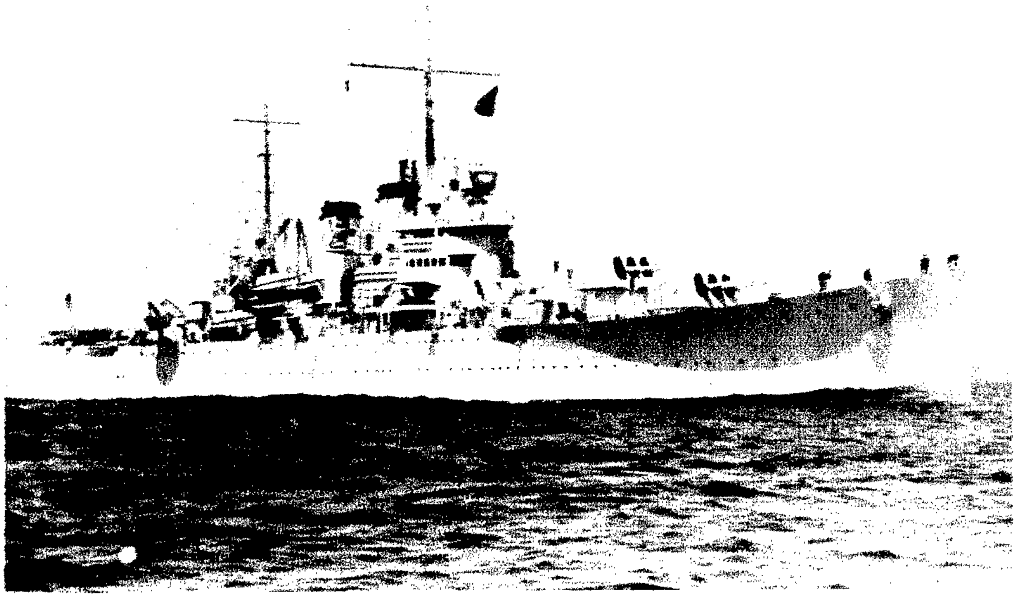

Figure 17: The pre-war CL 47, the *Boise,* shows the dots of portholes and portlights along her side extending fore and aft and near the waterline on the third deck. (NVS)

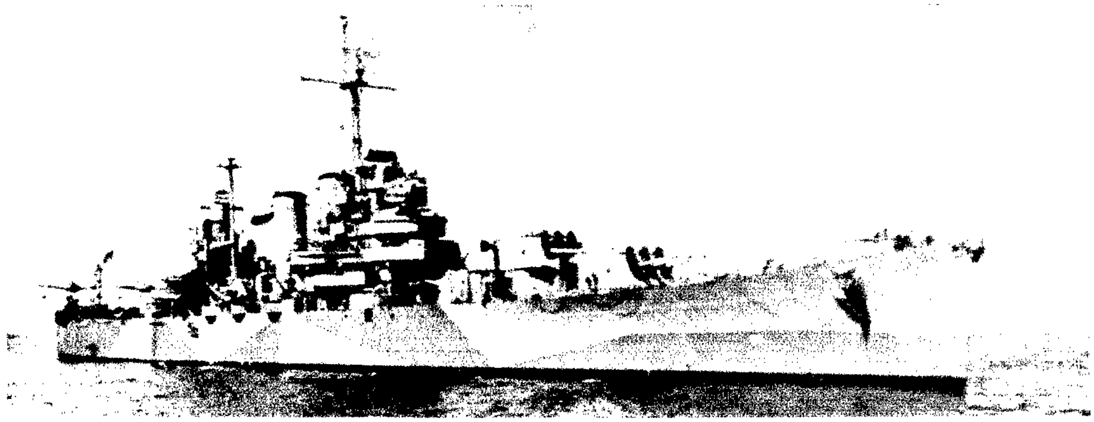

Figure 18: Although built with portholes, the sister CL *Nashville* shows them welded up for war. Ship has also picked up new, manpower consuming, radars and light AA guns. (NVS)

from fresh air, a glimpse of the outside and, when pressed, an emergency escape route.

The introduction of watertight compartmentation, while making the ship more damage resistant, also introduced a new horrible ways to die. The battleship *West Virginia* was sunk at Pearl Harbor in shallow water up to her main deck.(Figure 19). From the daily calendar marks made on the bulkhead, three men were trapped in a lower compartment Dec 7- Dec 23rd until the air ran out. (Smith, 2002) Their bodies and their calendar were found when the

ship was refloated May of 1942. A book published in 1944 reported three men were trapped below on the *Yorktown*, and in telephone communication with those above, when she sank. (Pratt 1944) In fact, the story was probably not true, since modern histories of that ships sinking do not include that incident but sailors reading that book in 1944 did not know that. Engineers conducting reactivation studies on the CA 134 class (designed late in WWII) in the 1980s found the ships to be both extremely well subdivided into watertight compartments but also outfitted with numerous escape trunks to avoid leaving men trapped below. Figure 20 shows the configuration of a hatch and scuttle system on the CA 134.

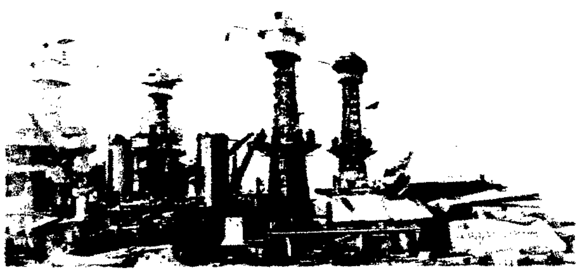

Figure 19: Battleship West *Virginia* sunk in shallow water at Pearl Harbor with men trapped below. (NVS)

Figure 20: Hatches and escape scuttles on the CA 134

British Destroyer Habitability

The British *Beagle* class of 1909 still used oil lamps for internal lighting with complaints from the crews of them producing more soot than light. The "M" class of 1913 still provided only cold water bathing for the crew and 18 inch hammock spacing. (March 1966) However, four large destroyers designed for use by the Chilean navy (taken over by RN during the WWI as the *Faulknor* class) were not as austere. They had electric radiators for compartment heating, a bakery, refrigerators, bathroom for engineers, and wash places for seamen.

The British "A" class destroyers of 1929 had six wash basins for 112 men, the C.P.O. and P.O. had three and the stokers three, with canvas and rubber bath tubs stowed overhead. The basins were supplied with hot water but it would take an ambitious sailor to drag down and assemble a collapsible tub and store it again, just to get a bath. It was proposed that the following 1930 "B" class have even fewer basins but be fitted with fresh water showers for the crew. The Admiralty staff raised objections that the showers would lead to an excessive

consumption of fresh water, requiring more distilling steam, so the fitting of showers was not approved. (March 1966)

In 1945, the Royal Navy moved major forces to the Pacific to join in the war against Japan. *Tribal* class destroyers, which had previously been serving with convoys to Russia, were found to be miserably hot in the tropics with inadequate ventilation. Temperatures as high as 160 degree F were reported in the galley. They even lacked water coolers so the crew could not even get an occasional convenient drink of cool water. (March, 1966) The "Z" class destroyers had their 9-1/2 inch portholes changed to 12-1/2 inch before deploying east, hoping to increase the air flow.

The *Battle* class of 1942 still depended on small buckets to wash clothes and topside drying in good weather and engine room hanging in bad. They also had no water coolers and 10 to 12 men shared a wash basin. A survey during the design following *Daring* class found that what the crew wanted in a new ship was USN style spring-open berths to finally replace hammocks. They also wanted the maintenance and laundering of bedding to be ship's task and not that of the individual sailor. (March 1966)

A comparison of the British *River* class escorts to the American designed *Colony* class sent to the RN as lend-lease shows the American ship had conveniences such a laundry, water cooler in each living area, automatic dishwashers, potato peelers, and cafeteria messing instead of taking food to the berthing area. The American ship's hull insulation, lighting, ventilation and internal communications system were superior to those on the British ship. The RN briefly thought about removing the luxury items to prevent their sailors from getting spoiled. (Brown 2000) Of course, when operating in company in the Pacific late in the War, the dry-ship Americans certainly noticed that the RN ships had scotch whiskey and beer aboard, and would pay a visit whenever possible.

Keeping the Crew Occupied

Row powered boats were carried on large ships well after reliable internal combustion boat propulsion was available. It was felt that boat rowing was good for keeping sailors in contact with the sea, giving them exercise and a fine leadership challenge for junior officers to win the fleet rowing competition (Figure 21)

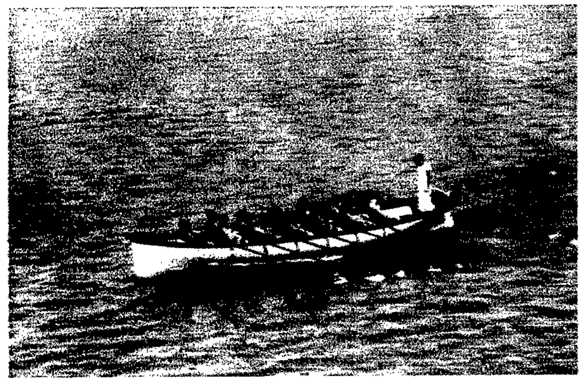

Figure 21: Rowing boat racing was thought to be good for the men. (NHC)

There was a similar competition between ships bands (Figure 22). The band of the Arizona won the competition Dec 6th 1941 and were promised to be allowed to sleep late the next morning as a reward.

Figure 22: Major ships had a band, both for own ship entertainment and for competition with rivals. (NHC)

In the early part of the century, crews were expected to put on their own plays and vaudeville acts supplemented by an occasional temperance lecture or magic lantern show. The arrival of movies, shown on deck, provided a new form of entertainment.

Sailors in the Movies

Sailors not only watch movies but show up in them also. Life at sea can provide source material for drama (*The Caine Mutiny*) or war reporting (*The Fighting Lady*) in any national culture but an odd cultural artifact of the US Navy was the singing and dancing battleship. The pre-World War II main Pacific fleet base was at Long Beach to the south of Hollywood. Writers, looking for exotic locations as a backdrop for musicals, decided that battleships were perfect. As described in Appendix I, there have been several 'warship musicals'. The fleet left peacetime Long Beach for Pearl Harbor in 1940 as a threat to supply lines of any Japanese military move south. The Japanese Navy took that location as a threat seriously.

Wartime Overcrowding

The coming of World War II placed major new mission demands on the existing hulls. Proliferation of light anti-aircraft guns (Figure 23), new sensors (radar, direction finding, sonar) coordinated by the newly invented Combat Information Center led to major increases in ships manning.

The 1917 vintage British "V" class destroyer was intended to have a 115 man compliment but had 135 in 1940 and 170 in 1942. (March 1966) Crewmen complained of becoming ill because of the overcrowding and lack of compartment heating. "Hard-lying" money was re-introduced to the RN for those ships for winter work (start of October to end of March). The "Z" class ships had been designed for 179 ratings but in May 1945 had 215 and, facing deployment to the Far East, with consequent increase need for self-maintenance, the ships were fitted for 237 men.

Figure 23: During WWII, a major new consumer of ships manpower was light anti-aircraft guns. (NHC)

FORWARD DEPLOYMENT DURING THE COLD WAR

A Change in Mission

The pre-WW II US navy had been a sail-to-battle Navy with most of the ships, most of the time, moored in a homeport. The berthing and human support spaces designs reflected that role; the ships were continually deployed during World War II but the sailors understood that there was a war on and accepted the conditions that they found themselves in. The coming of the Cold War required a new fleet deployment pattern of battlegroups on patrol around the world, so the ships designed for occasional deployment were used for continual deployment in a nominally peacetime environment. New weapons and electronics were being fitted to the ships, often at the expense of living and support spaces. By 1951, the Commander in Chief, Atlantic Fleet concluded that the addition of equipment and personnel to ships was adversely affecting their military effectiveness. His staff put together a 12 volume report on the problems. The first Chief of Naval Operations minimum habitability standard was issued in 1956. In 1960, new standards were issued stating that habitability was a military characteristic of ships of equal importance with other military features.

Evolving Standards

In 1952, one of the first ASNE papers on habitability, as a distinctive subject, argued that air conditioning, then fitted only to electronic spaces, could be used to make the crew more effective too. (Wells, 1952)

There was a long transitional period of trying to get new ships habitability to reflect the continuous forward deployment needs. Table E shows the evolving habitability standards during the 1960s and 70s. (Castle 1984) The USS *Northampton* (CLC-1) was the test ship for new improved crew furniture and, thus, the new bunks with a hard pan locker for stowage under the two lower bunks were called "Northampton" bunks (Figures 24 and 25). The possibility of going very high speeds in a Surface Effect Ships in the 1970s, with consequent motions and noise problems, required research into possibly severe human-ship interactions. (Skolnick 1974)

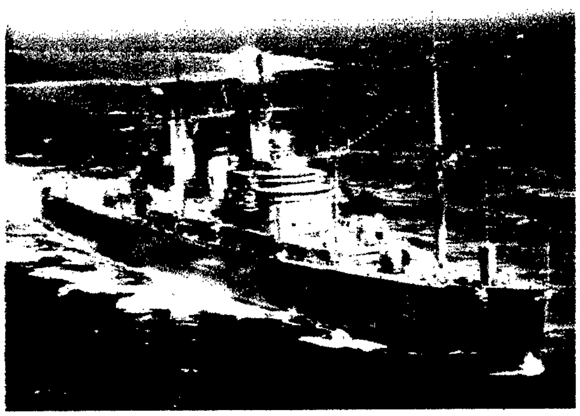

Figure 24: The Northampton, CLC-1, hard pan bunk test ship

Even with attempts at improvements, ships were still large moving pieces of machinery crowded with people. Appendix II is a 1970s vintage satire of life at sea but touches on the many irritants of life on a warship. A more formal 1971 *Proceedings* article covers many of the same complaints and notes the 7-to-9 square feet of living space per man on the aircraft carriers violated US Federal Prison minimum standards of 45 square feet per person. (Byington 1971) During the 1950s through 1970s, the era of the peacetime draft, the crews accepted miserable conditions only because being an infantry point man in a swamp was a worse option. The draft ended in 1973 placing the Navy, once again, in direct competition with civilian opportunities.

Figure 25: The next great improvement in crew berthing was the "Northampton' bunk. (HG)

Table E: Changing Enlisted Habitability Standards

Function	1960	1965	1979
Clear Headroom	6 ft 3 in	6ft 3 in	6ft 5 in
Crew Rec Seats	1per 10	1 per 3	1 per 3
Air conditioning	78 degrees	74 degrees	74 degrees
Wardrobe Locker	3 in	3 in	10 in
Civilian Clothes Space	No	No	Yes
Area per man	40 ft sq	45 ft sq	45 sq ft

After the Northampton bunk, the next stage in improving crew berthing were bunks with enclosed back and ends and a curtain on the walkway. The Lightweight Modular Berth provided only 18-20 inches between the mattress and the pan of the berth above. A sailor could sleep in that shallow space but turning over, for a broad shouldered person, could be a problem and reading or using small personnel electronic players was almost impossible. The current generation of improved furniture is the sit-up bunk, Figure 26, to be fitted to the LPD 17 class. (Filling, 1998)

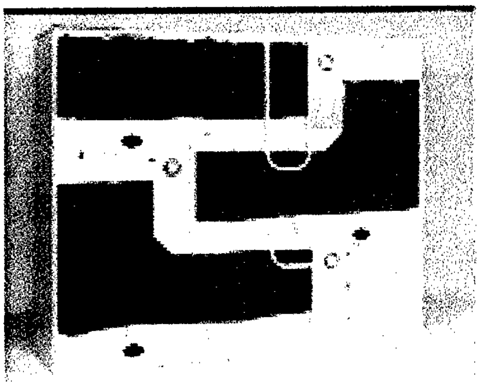

Figure 26: The sit-up crew bunks to be used on the LPD 17 class. (HPM)

Habitability and the Size of Ships

The perception of that habitability was a luxury item, which was making US Navy ships larger and more expensive than the competitors ships, would appear again in the "our ships are too big" drills of the 1970s. The Russian ships were widely praised as have more fighting power per ton of ship than the US ships. Comparative Naval architecture studies would show that US living space per man standards were generally less than that provided by foreign navies on their ships. (Kehoe 1976; Kehoe 1980) However, the total human support space allocation was larger on US ships because of fitting the ships with large storerooms, training and office spaces driven by the continuous forward deployment mission of the USN.

The Intelligent Ship

The ship's dependency on its own nervous system, increased with the use of computer networks, culminated with the USS *Yorktown*'s having a nervous breakdown (due to trying to divide by zero) and drifting helplessly for three hours in 1997.

A few ancient systems lingered on; the 1974 French ballistic missile submarine *La Redoutable*, now a museum display, had voice tubes fitted in the missile compartment to allow communication between decks

Women at Sea

The majority of changes to ships to allow women sailors were features that would have improved the life of the sailors even if the ships had remained all male: more compartments each with fewer bunks, and heads close by. (Castle 1974) There is one unavoidable conflict that will perpetually perplex future ship designers: any valve that the 5th percentile smallest woman can reach with her 73 inch reach , the 95th percentile man will bump his 72.8 inch high head on (Figure 27).

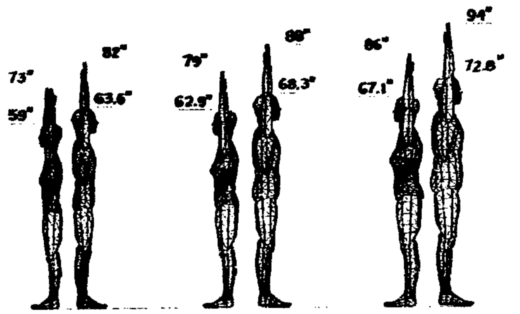

Figure 27: Comparison of men and women of the 5th, median, 95th percental

The Intelligent Sailor

Enlisted rating continue to include the classic functions of Boatswain's Mate (BM), Machinist's Mate(MM) and Gunner's Mate (GM). However, there are now Information System Technician (IT) and Navy Counselor (NC) ratings reflecting changes coming in from the outside world. The long term trend of the sailor's job changing from muscle to brains is exemplified by the existence of 'weight rooms' on board ships to allow modern crew to get exercise, something an early 1900s sailor never could have even conceived of needing.

The larger ships were fitted with their own TV stations. With at first cassettes and later CDs, the sailors increased their entertainment options by bringing their own players onboard. Increased linkage via satellite, allowing video and e-mail, eliminated the long delays inherent in using regular letters to communicate with family.

New Risks

While increasing environmental consciousness motivated continual efforts to remove asbestos, lead, PCBs and other existing source of risks to sailors, the same motivation created a new source of danger. Dumping sewage directly over the side may be bad for the harbor but it was safe for the ship's crew. Installation of Collecting-Holding-Transfer tanks, to eliminate close-to-shore dumping, also meant carrying tons of rotting biological material aboard with its off-gassing of poisonous Hydrogen Sulfide. At an open air shore-side sewage plant, the rotten egg smell is a nuisance but in the confines of a ship's compartment, it can be a sailor killer.

NATO Frigate

The 1980s NATO frigate project involved eight nations trying to create common ship design in order to reduce program costs and increase interoperability. It had, as one might expect, difficult issues about mission needs and industrial work sharing. One lesson learned from the failed project is how much a ship is the product of a nation's independent maritime culture. A small example was a stand-off over the design of the ship's bridge. One nation believed in giving junior officers as much responsibility as possible and wanted the control console to be pushed up against the pilot house windows to maximize the view. Another nation believed that the Captain should have walkway between the control console and the pilot house windows so that, in close maneuvering situations, he could both look outside and keep an eye on what the junior officer was ordering to be done. It was also intended that, on long boring watches at sea, to be a place for the captain to walk back and forth, and educate the junior officer on the traditions of the service. There was no possible engineering compromise between the national two approaches; the console either had to be forward or be pushed back.

In a similar situation, the first change needed by the Australians to their version of the FFG-7 class ships was to find a place for their Spirits Locker.

The Pleasure of the Sea

The sea can be a beautiful place, with startling sun sets and starry skies. The Military Sealift Command union contracts require a porthole in each sailors stateroom or a penalty payment for cutting him off from seeing the sea. Outside the ship, one

can see porpoises riding the wave ahead and great stormy petrels riding the airwake astern. There are exotic foreign ports to visit. The cruise line industry knows this and charges a substantial daily tariff for allowing one to live a, admittedly idealized, version of a sailor's lifestyle. Prior to cheap jumbo jet seats, "Join the Navy and See the World" was often the only way to do so (Figure 28). Prior to the invention of Underway Replenishment, the ships themselves required frequent stops at ports around the world so they could take on fuel and supplies, allowing the crew liberty.

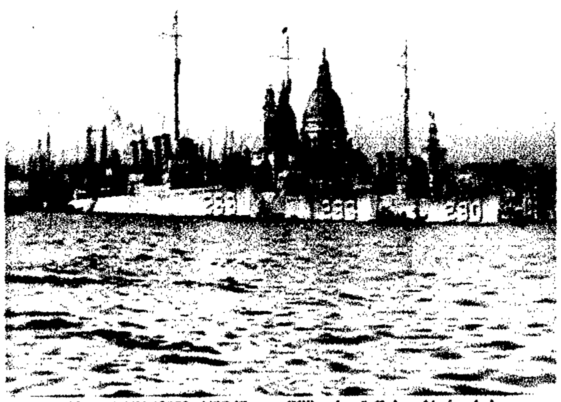

Photo # NH 93983 USS Flusser, Billingsley & Dale at Venice, Italy

Figure 28: Join the Navy to see the World – four pipers at Venice, Italy in the 1920s. (HG)

The Gradual Detachment of the Warship Sailor from the Pleasures of the Sea

The WWI diesel submarines had to spend much of their sea time on the surface for transit and to recharge batteries. With little freeboard, even to the coning tower, sub crew on deck, either as lookouts or for a smoke break, had plenty of contact with the sea. In fact, in bad weather, the external watch often had tons on it coming down on top of them. The introduction of nuclear power made them true submarines capable of very long submerged voyages with the crew sealed inside, totally out of contact with the sea. Prior to WWII, an airplane was essentially a fair-weather daylight machine and the sides of the flight deck were lined with light AA gun duty stations so the crew had substantial access to the outside. Due to the invention of technology to allow day/night all-weather operations late in WWII and the danger of jet blast, an aircraft carrier crew can be required to remain below for long periods of time. The only external access allowed is the smoker's sponson. Peering out through the cargo nets, hung over the sponson to prevent anyone from falling overboard, does not add much romance to the sea and sky.

The post-Cold War loss of overseas bases and the threat of terrorist attack, such as on the USS *Cole*, has greatly complicated going ashore for liberty compared to the 1950-60s. Ships will go into foreign ports less often and, for defensive measures, be berthed in remoter parts of the harbor. The demands on the USN to support the hot actions (Afghanistan, Iraq) and limited actions like Liberia has meant sending ships to sea for 100-200 days – deployment durations, without port visits, that hadn't been seen since the days of sail.

THE 21ST CENTURY

The planned next generation of ships continue the long term process of improving the living condition for enlisted. The proposed DDX is to have a major reduction in number of sailors per ton of ship but also with living spaces broken into small compartments, each for a few men and more space per man.

The concept pictures of the DDX has a smooth topside, free of life rails and small platforms to stand on (Figure 29). This is driven both by need for a reduction of signature and to avoid radar beam blockage and radiation hazards of the high-powered conformal antennas. On such a ship, even the surface combatant sailors will have lost places topside to quietly view the sea and sky. Throughout the fleet, the seaman is

gradually losing the pleasure of the contact with the ocean.

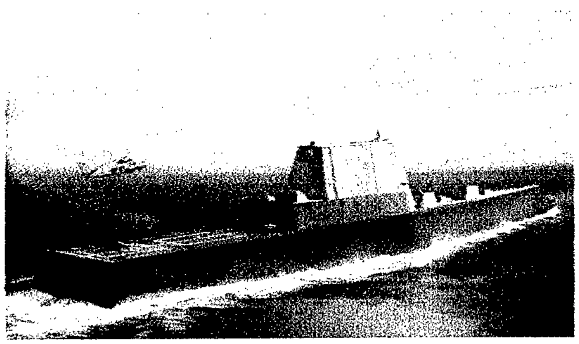

Figure 29: The military need of smooth topsides cut off future sailor from the sea. (USN)

Conclusions

The adventure tales of Horatio Hornblower and Jack Aubery aside, in reality the wooden sailing ship was man-killer. The first changes needed to ships was to prevent them from harming their crew; those changes came from policy changes, planned introduction of technology, and reforms forced on the Navy by the outside culture. Progress has not always been automatically for the better with propulsion machinery introducing new poisons inside the ship and the ability to smash the crew about by driving into a seaway. Many things we think of as ancient, such a hammocks for sleeping, lasted well into the 20th century. However, the long term trend for ships is to treat sailors better since a modern navy needs brains, and not muscle, and must compete with the larger outside society for that talent. The one bad feature of the long term warship design trends is the increasing detachment of sailors from the pleasures of the sea as military needs, such as low signature topsides, force them inside the ship and world events hinder pleasant foreign port calls.

Appendix I: Singing and Dancing Sailors

While the HMS *Pinafore* may have been the original singing warship, the USN was the leader in the movie era. The definitive singing sailor movie was *Follow the Fleet* (RKO, 1935) featuring Fred Astaire and Ginger Rogers. *Shipmates Forever* (Warner Bros, 1935) has Dick Powell as ensign who would rather sing than run a ship. In *Born to Dance* (MGM, 1937), Eleanor Powell tap dances on a sound stage imitation battleship. In spite of its title, *This is the Army* (Warner Bros, 1943) also has a sound stage battleship number. *On the Town* (MGM, 1949) has sailors Frank Sinatra and Gene Kelly coming ashore from their destroyer to dance through New York. Finally, the 1989 Cher music video "If I Could Turn Back Time" was filmed on the battleship *New Jersey* with several hundred crewmen as extras.

Appendix II: Shipboard Life at Home

Prior to the Internet, there was the photocopy-net where progressively grayer and random-spotted copies-of-copies were passed around by hand. This anonymous author's work is, from internal references, set in the late-1970s and was circulated around NAVSEA. The author must not have been in the machinery department because he fails to mention the free 100 degree F, 100% humidity saunas provided to those crewmen by the steam plants of the era:

"<u>How to Simulate Shipboard Life at Home</u>

1. When commencing this simulation, remember to lock all friends and family outside, communicating only with letters that your neighbor will hold for two

weeks before delivering, losing one out of every five.

2. Unplug all radios and television to cut yourself off completely from the outside world, but have a neighbor bring you Time and Newsweek from last month, and a Playboy magazine with all the photos cut out.
3. Surround yourself with 800 people you don't like. People who chain-smoke, fart loudly, snore like a Mack truck on an uphill grade, and use expletives in speech the way kids use sugar on cold cereal are good choices for this.
4. Monitor all operating home appliances hourly, recording vital parameters (plugged in, light comes on as door is opened, etc.). If not in use, log as "secured".
5. Do not flush toilets for the first three days to simulate the smell of forty persons using the same commode. After that, flush once daily.
6. Wear only approved coveralls or proper Marine Corps uniforms. No special t-shirts or cutoffs. Even though nobody really cares, once a week clean and press one uniform, wear it for twenty minutes, after which you must change back into coveralls.
7. Cut your hair weekly, making it shorter each time until you are bald or you look like you tangled with a demented sheepshearer.
8. Work in 18-hour cycles, sleeping only four hours at a time to ensure your body doesn't know or care if it's daytime or nighttime.
9. Listen to your favorite cassette six times a day for two weeks, then play music that causes acute nausea until you are glad to get back to your "favorite" cassette.
10. Cut a single bed in half lengthwise, and enclose three sides. Add a roof that prevents you from sitting in any position (18" is a good height). Place a dead animal under your bed to simulate smell of your cubemates sheets.
11. Set your alarm clock to go off at the "snooze" interval for the first hour of sleep to simulate the various alarms of watchstanders and night crew going off at odd times. Place your bed on a rocking table to ensure that you're tossed from side to side for the remaining three hours. Alternatively use a custom built alarm clock that sounds like a fire alarm, a police siren, and a new wave rock band combined so that you will not become accustomed to ignoring your alarm clock.
12. Prepare all food while blindfolded, using all the spices that you can grope for, to simulate shipboard food. Remove the blindfold and eat as fast as humanly possible. If the food does not stick to inverted plate when cold, use more lard. If food contains more than one part per thousand of fiber, dispose of it. Always take more than you can possibly eat to keep up the waste standards of the Navy.
13. Periodically shut off power at the main breaker and run around screaming "Fire in the main engine! Fire in the main engine!". Do this until you sweat profusely or lose your voice, then restore power.
14. Buy a gas mask and scrub the faceplate with steel wool until you can't see out of it. Wear this for two hours every fifth day, even to the bathroom.
15. Prepare yourself for an emergency that will require you to evacuate the premises, knowing that if you exit, the biker gang you hired will simulate sharks and cut off your arms and legs. Study first aid for bleeding until you can quote the book verbatim.
16. Study the owner's manual for all appliances in the dwelling; then at regular intervals, take each one apart and put it back together again, then test operate it at the extremes of its tolerance.
17. Remove all plants, pictures and decorations. Paint all furnishings gray, white, or the shade of green found on hospital O.R. smocks.
18. To make sure you are living in a clean and happy environment, every week

clean from top to bottom, working hard all day even if it only takes three hours. Whenever possible repeat your efforts. When complete inspect your work, criticizing as much as possible. Never be satisfied with a good solid effort.

19. Once a day plug in your TV to watch a movie that you walked out on last year, and then watch an episode of Charlie's Angels that you didn't like the first two times you saw it.
20. Since you have no doctor, stock up Band-Aids, aspirin, Robitussin and Actifed, which have been proven as cures for every disease known to man.
21. Every three weeks, go outside directly to the city slums, wearing your best clothes, and enter the raunchiest bar you can find and ask the bartender for the most expensive imported beer he carries. Drink as many of these as you can in four hours, then hire a cab to take you back by the longest route he can find. After tipping the cab driver, after he doubled the shown fare because you were dressed funny, lock yourself back in your dwelling for another three weeks.
22. This simulation must run for a minimum of six months to be effective. The exact date of the end of the simulation will be changed no fewer than seven times without your knowledge. This is done to keep you guessing as to when you can expected to get back to a semi-normal life. It is also done in hopes of screwing up any plans you have made or would like to make.

This guide was designed for those who would like to, but haven't had the chance to, enjoy an extended period of time at sea. Happy sailing!"

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HHC = Naval Historical Center, NVS = Navsource internet site, HG = Haze Gray internet site, HPM = Hopeman Brothers internet site, USN = Navy released.

Philip Sims graduated from Webb Institute in 1971 and went to work for the Advanced Design Branch of the Naval Ship Engineering Center (now NAVSEA). He was part of the FFG 7 design team in 1972. From 1973 to 1975 he was involved in creating automated early stage aircraft carrier design procedures and performing carrier design studies as part of the Sea Based Air Study and CVV design. He returned to school in 1976 for a master's degree at MIT. The 1977-80 period was spent in updating the Navy's destroyer-cruiser early stage design procedures and conducting design studies for the CGN 41, the reserve FFX, and the DDX (later DDG 51) projects. During this period he was also team leader on Surface Ship Concept Formulation (CONFORM) studies of new ships such as a heavy combatant and a survivable cruiser. From 1981-83 he was the naval architect on the BB 62 modernization/ reactivation and Ship Design Manager for the BB 61 and CA 134. He was member of the NATO Staff Requirements Working Group for the NATO Frigate Replacement for the 1990s (NFR 90) and the principle naval architect on NFR 90 at NAVSEA. The early 1990s were spent on CGN, DDG 993 and CG 47 modernization studies. He conducted Navy studies of the Arsenal Ship, prior to the award to industry teams, followed by review of the industry ships. He prepared destroyer/frigate studies as part of the Force Architecture phase of SC 21. In 1999, he started conducting the first pre-milestone A studies of JCC(X) and stayed with the program until the cancellation in 2003. He currently conducts Comparative Naval Architecture studies and starting the very early work on the CG(X).